PROCESS AND PLANT FOR REDUCING SOLIDS CONTAINING IRON OXIDE

The present invention relates to a process and a plant for reducing solids containing iron oxide, in particular iron ore, in which fine-grained solids are heated and at least partly calcined in a preheating and/or calcining stage, are prereduced in a first fluidized-bed reactor downstream of the preheating and/or calcining stage, and are reduced in a second fluidized-bed reactor and briquetted in a briquetting stage downstream of the second reactor at a temperature above 500°C.

From DE 44 10 093 C1 there is known such a process for the direct reduction of iron ores to obtain sponge iron (DRI), in which in a first reactor with circulating fluidized bed a prereduction is effected at temperatures between 550 and 650°C. In a downstream second reactor with classical fluidized bed, into which heated gas containing hydrogen is introduced as reducing agent for fluidizing purposes, the solids are further reduced, so that the product for instance has a degree of metallization of more than 90%.

During the transport of sponge iron (DRI), the iron is usually briquetted for safety reasons, for instance because of the risk of fire and because of the better handling (formation of dust). Such briquetting is effected subsequent to the reduction of the iron, the still hot sponge iron mostly being cooled while being supplied to the briquetting plant. For increasing the strength of the briquet it is, however, desirable that briquetting takes place at rather high temperatures of e.g. about 700°C. At this temperature, however, the fine-grained sponge iron has a very poor flow behavior, which makes briquetting more difficult. To improve the flow behavior of spong iron and ensure a good processability, about 0.5 wt-% magnesium oxide (MgO) is added to the sponge iron prior to briquetting through a pressure feeder upstream of the briquetting plant. Magnesium oxide has no measurable negative influence on the strength or stability of the sponge iron briquet, but it is expensive due to costly processing steps, so that the manufacturing costs for sponge iron briquets are also rising. In addition, magnesium oxide is hygroscopic and very fine-grained, usually with a grain size below 100 µm, so that it is difficult to store and to use.

A process of producing sponge iron from oxidic iron ores is also known from DE-OS 1 458 756, in which the reduction should be effected at rather high temperatures. To avoid an effect known as bogging or fouling, which occurs during the reduction at such high temperatures and in which the solids stick or weld together to form agglomerates, so that the fluidized bed sinks down in the reduction reactor, the addition of about 0.05 wt-% of very finely ground oxides or carbonates of magnesium is proposed. These additives should be rather fine-grained and preferably have a grain size of distinctly less than 297 µm, in particular less than 44 µm. However, this also leads to the above-described problems during the storage or use of the additives. In addition, in this process the additives must be added to the iron ore e.g. via a pressure feeder before the reduction stage. This leads to a rise in the investment costs for a plant for performing the process. Due to the lower temperatures in the reduction stage, a comparatively poor calcination is achieved in this known process, when carbonates of magnesium are added to the reduction stage. This can only be compensated by longer retention times, which are, however, likewise undesirable. On the other hand, these problems do not occur when magnesium oxide is added to the reduction stage instead of carbonates of magnesium. However, this involves the above-mentioned disadvantages of the high costs and the poor handling properties of magnesium oxide.

Therefore, it is the object of the present invention to provide a process and a plant for reducing solids containing iron oxide, which is characterized by an improved flow behavior of the product and a lower consumption of energy.

In accordance with the invention, this object is solved by a process as mentioned above, in which magnesite ($MgCO_3$) together with the solids containing iron oxide is added to the preheating and/or calcining stage, which magnesite is at least partly calcined in the preheating and/or calcining stage to obtain magnesium oxide. As compared to magnesium oxide, magnesite is available at a distinctly lower price, so that the costs for producing briquets from sponge iron can be decreased. Since the magnesite is at least partly calcined to obtain magnesium oxide, the flowability of the sponge iron prior to briquetting is improved. Briquetting therefore can also take place at high temperatures, at which the flow behavior of the sponge iron usually is deteriorated. By means of this hot briquetting, the strength of the briquet is increased as compared to cold briquetting at lower temperatures.

Since the magnesite is heated in the preheating and/or calcining stage together with the solids containing iron oxide, the supply of heat to the two reactors for reducing the solids containing iron oxide need not be ensured by a strong heating of the reducing agent, e.g. hydrogen. The energy efficiency of the endothermal reduction process hence can be increased in that the solids containing iron oxide and the magnesite are heated already in the preheating and/or calcining stage to the temperature required for reduction.

Due to the common supply of the solids containing iron oxide and the magnesite into the preheating and/or calcining stage it is not necessary to add additional magnesium oxide to the solids before a pressure feeder upstream of the reactors. In this way, the investment costs for the commonly used separate supply of magnesium oxide are also eliminated. The magnesite frequently contains impurities such as iron oxide and/or limestone, which do not disturb the further processing steps, but are in part even desired for the further processing of the iron.

The energy efficiency of the process of the invention can further be increased in that the magnesite together with the solids containing iron oxide is calcined in the preheating and/or calcining stage at temperatures of 400 to 1250°C, in particular at 540 to 1000°C. In accordance with the invention, the temperature range for calcining can also lie between 1000 and about 1250°C. Due to the particularly high temperatures in the preheating and/or calcining stage, as compared to the known processes, the supply of heat for the endothermal reduction of iron oxide by means of hydrogen need not be effected by a strong heating of the hydrogen commonly used as reducing agent.

In accordance with a preferred embodiment of the invention, more than 50 %, preferably about 90 %, of the magnesite added to the preheating and/or calcining stage together with the solids containing iron oxide have a grain size between 300 µm and 3 mm, in particular between 400 µm and 1 mm. For the process in accordance with the invention there can also be used magnesite with a grain size between 1.25 and 3 mm. The storage and the handling properties of the magnesite are improved thereby without deteriorating the flowability of the sponge iron. In the course of the process, the relatively coarse-grained magnesite or the magnesium oxide is ground in the preheating

and/or calcining stage or in the reactors provided downstream of the same. The applicability of the magnesium oxide in briquetting thereby is increased without deteriorating the handling properties of the additives.

An improved flow behavior and a good processability of sponge iron, in particular in the briquetting stage, is achieved in accordance with the invention when between 0.1 and 5 wt-%, in particular about 0.5 wt-% magnesite is added to the solids containing iron oxide before and/or during the supply into the preheating and/or calcining stage. The solids supplied to the briquetting stage from the second reactor contain for instance between 0.1 and 5 wt-%, in particular about 0.5 wt-% magnesium oxide, which was obtained by calcining the magnesite in the preheating and/or calcining stage. To further improve the processability of the solids reduced in the second reactor in the briquetting stage, the same can be heated together with the magnesium oxide in a heating stage upstream of the briquetting stage to a temperature above 600°C, in particular about 700°C, and can be introduced into the briquetting stage in the hot condition. This provides for a further reduction of the energy required for forming in the briquetting stage.

To largely avoid the formation of agglomerates in the reactors during the reduction, the solids containing iron oxide are reduced in the first and second reactors, preferably at temperatures below 700°C, in particular at about 630°C. At these temperatures, the bogging effect known from the prior art does not occur. As a result, the magnesite supplied to the preheating and/or calcining stage is not required already in the reduction stage for forming magnesium oxide, but ensures the flowability of the sponge iron during the supply to a briquetting plant. The degree of fluidization of the solids containing iron oxide in the first and second reactors hence is particularly high during the reduction, so that there can occur a good transfer of heat and a good reaction with the reducing agent. The solids containing iron oxide are reduced in the first and second reactors to obtain metallic iron with a degree of metallization of more than 75 %, in particular more than 90 %.

The object underlying the invention is further solved with a plant for reducing solids containing iron oxide, comprising a preheating and/or calcining stage, a first and a second reactor each constituting a fluidized-bed reactor, and a briquetting stage, in that the preheating stage includes means for the simultaneous continuous or discontinuous

introduction of iron-oxide-containing solids and magnesite, and that upstream of the briquetting stage a heating stage is provided. Since iron-oxide-containing solids and magnesite are introduced together, the same are heated in the preheating and/or calcining stage, so that the heat required for the subsequent endothermal reduction of the iron oxide need not be ensured by a strong heating of the reducing agent. The heating stage upstream of the briquetting stage also makes it possible that the sponge iron withdrawn from the reduction reactors together with magnesium oxide obtained from the magnesite can be heated to a temperature of for instance about 700°C, which is optimal for briquetting. The reduction can be effected at comparatively low temperatures, so that the inclination of the iron oxide to form agglomerates is largely suppressed.

The two series-connected reactors, in which the reduction takes place, can for instance be fluidized-bed reactors with a stationary fluidized bed. To provide for improved mass and heat transfer conditions during the reduction, at least one of the two reactors should, however, preferably be a fluidized-bed reactor with a circulating fluidized bed or an annular fluidized bed.

In accordance with a preferred embodiment of the invention, the first and/or the second reactor has a plurality of nozzles or inlet openings for supplying a heated, gaseous reducing agent, such as hydrogen. The reducing agent can also be used for fluidizing the solids reduced in the reactors.

The energy efficiency of the plant in accordance with the invention can be improved in that the preheating and/or calcining stage includes a first preheater, for instance a Venturi preheater, with a downstream first cyclone and a second preheater (calcining stage) with a downstream second cyclone, the first and/or the second cyclone being connected with the first Venturi preheater via a conduit for recirculating dust separated from waste gas. The dust heated in the preheating and/or calcining stage thus is utilized for preheating the solids containing iron oxide and the magnesite.

Further developments, advantages and possible applications of the invention can also be taken from the subsequent description of an embodiment and the drawing. All features described and/or illustrated in the drawing form the subject-matter of the invention

per se or in any combination, independent of their inclusion in the claims or their back-reference.

The only Figure shows a process diagram of a process and a plant in accordance with an embodiment of the present invention. In the process for reducing solids containing iron oxide as shown in the Figure, for instance moist iron ore together with magnesite ($MgCO_3$) is introduced via a supply conduit 1 into a Venturi preheater 2, in which the solids containing iron oxide and the magnesite are dried and heated. Via conduit 3, the solids containing iron oxide together with the magnesite are introduced into a cyclone 4, in which the dust-laden waste gases are separated from solids.

Via conduit 5, the dust-laden waste gases are supplied to a filter 6, for instance an electrostatic precipitator or a scrubber, from which the dust is recirculated to the preheating stage via conduit 7.

The solids separated from the waste gas in the cyclone 4 are supplied via conduit 8 to a calcining stage 9 or a second preheater to which a burner 9a is associated, by means of which a major part of the energy is supplied to the process. In the calcining stage 9, the solids and the magnesite are preheated to a temperature of for instance about 850°C. Due to this high temperature in the calcining stage 9, the magnesite is calcined to obtain magnesium oxide, which together with the solids containing iron oxide is supplied via conduit 10 to a second cyclone 11. Therein, the solids are separated from dust-laden waste gas, which is supplied to the first Venturi preheater 2 via conduit 12. As a result, the solids containing iron oxide and the magnesite are heated and dried in the Venturi preheater 2 by the waste gases of the second cyclone 11.

The solids separated in the second cyclone 11 are supplied via a conduit 13 with pressure feeder to a first reactor 14, which for instance includes a circulating fluidized bed. By supplying hydrogen, the heated ore containing iron oxide is prereduced in the first reactor 14 and via conduit 15 introduced into a second reactor 16, which can be a stationary fluidized-bed reactor. Heated hydrogen as reducing agent is also introduced into the second reactor 16, so that the iron oxide is reduced in the second reactor 16.

From the second reactor 16, sponge iron with a high degree of metallization is withdrawn together with magnesium oxide and via conduit 17 introduced into a heating stage 18, in which the solids are heated to a temperature of about 700°C and via conduit 19 are introduced into a briquetting stage 20 in the hot condition.

Downstream of the reactors 14 and 16 recirculating cyclones can be provided, in which dust-like solids are separated from the gases leaving the reactors. In a waste gas treatment stage 21, these waste gases can be cleaned and be heated in a heater 22, before they are recirculated to the reactors 14, 16.

Example (Reduction of Iron Ore)

In a plant corresponding to the Figure, 61.2 t/h of moist iron ore with 7.8 % moisture and 300 kg/h of magnesite with a grain size of less than 1 mm were supplied to the Venturi preheater 2 via conduit 1. Together with the magnesite, the iron ore was dried and heated in the Venturi preheater 2 and introduced via the cyclone 4 into the calcining stage 9, in which the iron ore and the magnesite were heated to a temperature of 850°C.

From the dust-laden waste gases separated in the cyclone 4, 2.6 t/h of dust were separated in the filter 6, which dust contained 25 kg/h of magnesium oxide. This dust was recirculated to the preheating stage via conduit 7.

54.2 t/h of the iron ore heated to 850°C in the preheater 9 together with 150 kg/h of magnesite calcined to magnesium oxide were introduced via conduit 13 with pressure feeder into the reactor 14 and the reactor 16 provided downstream of the same. The reduction in the reactors 14 and 16 at a temperature of about 630°C provided 37 t/h of a product with a degree of metallization of 91 %. The product which contained about 34 t/h of metallic iron and 150 kg/h of magnesium oxide was introduced via conduit 17 into the further heating stage 18. In the same, the metallic iron and the magnesium oxide were heated to 700°C and via conduit 19 were introduced into the briquetting stage 20 in the hot condition.

List of reference numerals:

1	conduit
2	(first) Venturi preheater
3	conduit
4	(first) cyclone
5	conduit
6	filter
7	conduit
8	conduit
9	calcining stage (second preheater)
9a	burner
10	conduit
11	(second) cyclone
12	conduit
13	conduit with pressure feeder
14	(first) reactor
15	conduit
16	(second) reactor
17	conduit
18	heating stage
19	conduit
20	briquetting stage
21	waste gas treatment stage
22	heater